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NON-PROVISIONAL PATENT APPLICATION

CROSS REFERENCE TO RELATED APPLICATIONS

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This application is a divisional application of co-pending application Serial Number 10/072,587, filed February 8, 2002 and claims the benefit of U.S. Provisional Application number 60/267,306 filed on February 8, 2001. The subject matters of the prior applications are incorporated in their entirety herein by reference thereto.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with government support under Contract No. N00024-01-C-4034 awarded by the United States Navy.

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TITLE

Current Control Device

BACKGROUND OF THE INVENTION

1. Field of the Invention

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The present invention generally relates to a current control device for regulating current flow via compression and expansion of a composite.

2. Related Arts

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Mechanical circuit breakers are best described as a switch wherein a contact alters the electrical impedance between a source and a load. Mechanical breakers are typically composed of a snap-action bimetal-contact assembly, a mechanical latch/spring assembly, or an expansion wire. Such devices are neither gap-less nor shock resistant, therefore prone to chatter and subject to arcing. Chatter and arcing pose substantial problems in many high-voltage applications.

1 Variably conductive composites are applicable to current control devices.
Compositions include positive temperature coefficient resistive (PTCR), polymer current
limiter (PCL), and piezoresistive formulations. PTCR and PCL applications and
compositions and piezoresistive compositions are described in the related arts.

5 Anthony, United States Patent No. 6,157,528, describes and claims a polymer
fuse composed of a PTCR composition exhibiting temperature-dependent resistivity
wherein low resistivity results below and high resistivity results above a transition
temperature.

10 PTCR composites are composed of a conductive filler within a polymer matrix
and an optional nonconductive filler. Chandler et al., United States Patent No. 5,378,407,
describes and claims a PTCR composite having a crystalline polymer matrix, a nickel
conductive filler, and a dehydrated metal-oxide nonconductive filler. Sadhir et al., United
States Patent No. 5,968,419, describes and claims a PTCR composite having an
amorphous polymer matrix, a thermoplastic nonconductive filler, and a conductive filler.
15 During a fault, the composite heats thereby increasing volumetrically until there is
sufficient separation between particles composing the conductive filler to interrupt current
flow. Thereafter, the composite cools and shrinks restoring conduction. This self-restoring
feature limits PTCR compositions to temporary interrupt devices.

20 PCL composites, like PTCR compositions, are a mixture of a conductive filler
and a polymer. However, PCL composites are conductive when compressed and interrupt
current flow by polymer decomposition. For example, Duggal et al., United States Patent
22 No. 5,614,881, describes a composite having a pyrolytic-polymer matrix and an

1 electrically conductive filler. During a fault, temperature within the composite increases
causing limited decomposition and evolution of gaseous products. Current flow is
interrupted when separation occurs between at least one electrode and conductive
polymer. Gap dependent interrupt promotes arcing and arc related transients.

5 Furthermore, static compression of the composites increases time-to-interrupt by damping
gap formation. Neither PTCR nor PCL applications provide for the dynamically-tunable
compression of a composite in response to electrical load conditions.

Piezoresistive composites, also referred to as pressure conduction
composites, exhibit pressure-sensitive resistivity rather than temperature or decomposition
10 dependence. Harden et al., United States Patent No. 4,028,276, describes piezoresistive
composites composed of an electrically conductive filler within a polymer matrix with an
optional additive. Conductive particles comprising the filler are dispersed and separated
within the matrix, as shown in FIGS. 1A and 1C. Consequently, piezoresistive composites
are inherently resistive becoming less resistive and more conductive when compressed.

15 Compression reduces the distance between conductive particles thereby forming a
conductive pathway, as shown in FIGS. 1B and 1D. The composite returns to its resistive
state after compressive forces are removed. However, piezoresistive compositions resist
compression.

Pressure-based interrupt facilitates a more rapid regulation of current flow as
20 compared to PTCR and PCL systems. Temperature dependent interrupt is slowed by the
poor thermal conduction properties of the polymer matrix. Decomposition dependent
22 interrupt is a two-step process requiring both gas evolution and physical separation

1 between electrode and composite. Furthermore, decomposition limits the life cycle of a
composition.

Active materials, including but not limited to piezoelectric, piezoceramic,
electrostrictive, magnetostrictive, and shape-memory alloy materials, are ideally suited for
5 the controlled compression of piezoresistive composites thereby achieving rapid and/or
precise changes to resistivity. Active materials facilitate rapid movement by mechanically
distorting or resonating when energized. High-bandwidth active materials are both
sufficiently robust to exert a large mechanical force and sufficiently precise to controllably
adjust force magnitude.

10 As a result, an object of the present invention is to provide a current control
device tunably and rapidly compressing a pressure-dependent conductive composite. A
further object of the present invention is to provide a device that eliminates arcing thereby
facilitating a complete current interrupt. It is an additional object of the present invention
to provide a device that quenches transient spikes associated with shut off.

15 SUMMARY OF THE INVENTION

The present invention is a current control device controlling current flow via
the tunable compression of a polymer-based composite in response to electrical load
conditions. The composite is compressed by a nonconductive pressure plate and current
flow occurs between two electrodes contacting the composite. The composite is variably-
20 resistive and typically composed of a conductive filler, examples including metals, metal-
nitrides, metal-carbides, metal-borides, metal-oxides, within a nonconductive matrix,
22 examples including polymers and elastomers. Optional additives typically include oil,

1 preferably silicone-based.

A compression mechanism applies, varies, and removes a compressive force acting on the composite. Compression mechanisms include electrically driven devices comprised of actuators composed of an active material extending and/or contracting when energized. Active materials include piezoelectric, piezoceramic, electrostrictive,
5 magnetostrictive and shape memory alloys. Piezo-controlled pneumatic devices are also appropriate. Actuator movement adjusts the pressure state within the composite thereby altering resistivity within the confined composite.

Several advantages are offered by the present invention. Compression-based control of a pressure-sensitive conduction composite provides a nearly infinite life cycle. A
10 gap-less interrupt eliminates arcing and arc quenching requirements. The present invention lowers fault current thereby avoiding stress related chatter. Parallel arrangements of the present invention offer power handling equal to the sum of the individual units.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic diagram showing exemplary microstructures for composites before and after compression.

FIG. 2 is a flowchart of composite manufacturing method.

20 FIG. 3 is a side elevation view of a pressure switch with conductive pressure plates.

FIG. 4 is a side elevation view of a pressure switch with nonconductive pressure plates.

22 FIG. 5 is a side elevation view of a current controller comprised of four pressure switches

1 wherein pressure plates are pushed by actuators.

FIG. 6 is a side elevation view of a current controller comprised of four pressure switches wherein pressure plates are pulled by actuators.

FIG. 7 shows a parallel arrangement of current controllers comprising a single unit.

5 FIG. 8 is a perspective view of current control device.

FIG. 9 is a section view showing composite confined between isolator elements.

FIG. 10 is a section view showing composite confined by isolators and pressure plates.

FIG. 11 is a perspective view showing composite confined within compression device.

FIG. 12 is a perspective view of one end of current control device showing details of

10 compression-release mechanism.

FIG. 13 is a top elevation view of pressure switch showing cylindrical pores oriented through electrodes.

FIG. 14 is a section view of pressure switch showing cylindrical holes through switch thickness.

15 FIG. 15 is a section view of pressure switch showing cylindrical holes within composite.

FIG. 16 is a section view of pressure switch showing cylindrical holes filled with a temperature sensitive material.

FIG. 17 is a side elevation view of temperature activated switch.

FIG. 18 is a side elevation view of temperature activated switch.

20 REFERENCE NUMERALS

1 Current controller

22 2 Conductive filler

1	3 Nonconductive matrix
	4 Composite
	5 Isolator
	6 First electrode
5	7 Second electrode
	8 Slider
	9 Channel
	10 Terminal end
	11 Pressure switch
10	12 Cavity
	16 Compression mechanism
	18 Pressure plate
	19 Actuator
	20 First end
15	21 Second end
	22 Force
	23 Guide
	25 Band
	30 Restoration element
20	31 Conductor
	32 Insulator
22	33 Insulator

- 1 40 Hole
41 Temperature sensitive material
50 Mechanical spring
51 Temperature sensitive actuator
5 52 Wire
53 Wire
54 Nonconducting terminal
55 Rigid element
56 Thermal element

10 DESCRIPTION OF THE INVENTION

Two embodiments of the present invention are comprised of a rectangular solid composite 4 contacting and sandwiched between two or more plates, namely a planar first electrode 6 and a planar second electrode 7, as shown in FIG. 3, and a planar first electrode 6 and a planar second electrode 7 and two planar pressure plates 18a, 18b, as shown in FIG. 4. A pressure switch 11 is comprised of a composite 4 and electrodes 6, 7
15 as shown in FIG. 3 or a composite 4 and pressure plates 18a, 18b as shown in FIG. 4.

The composite 4 functionally completes the current path between first electrode 6 and second electrode 7 during acceptable operating conditions and interrupts current flow when a fault condition occurs. The composite 4 is either conductive or
20 resistive based on the pressure state within the composite 4. For example, the composite 4 may be conductive above and nonconductive below a threshold pressure. Alternately, the resistivity of the composite 4 may vary with pressure over a range of resistance values.
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1 A typical composite 4 is a pressure dependent conductive material, for
example a piezoresistive formulation, comprised of a nonconductive matrix 3 and a
conductive filler 2, as schematically shown in FIG. 1. Preferred mixtures have a volume
fraction below the percolation threshold wherein conductive filler 2 is randomly dispersed
5 within the nonconductive matrix 3. During compression, the nonconductive matrix 3
between conductive filler 2 particles is dimensionally reduced thereby crossing the
percolation threshold.

 The nonconductive matrix 3 is a resistive, yet compressible material including
but not limited to polymers and elastomers. Specific examples include polyethylene,
10 polystyrene, polyvinylidene fluoride, polyimide, epoxy, polytetrafluoroethylene, silicon rubber,
polyvinylchloride, and combinations thereof. Preferred embodiments are comprised of the
elastomer RTV R3145 manufactured by the Dow Corning Company.

 The conductive filler 2 is an electrically conductive material including but not
limited to metals, metal-based oxides, nitrides, carbides, and borides, and carbon black.
15 Preferred fillers resist deformation under compressive loads and have a melt temperature
sufficiently above the thermal conditions generated during current interrupt. Specific metal
examples include aluminum, gold, silver, nickel, copper, platinum, tungsten, tantalum,
iron, molybdenum, hafnium, combinations and alloys thereof. Other example fillers include
Sr(Fe,Mo)O₃, (La,Ca)MnO₃, Ba(Pb,Bi)O₃, vanadium oxide, antimony doped tin oxide,
20 iron oxide, titanium diboride, titanium carbide, titanium nitride, tungsten carbide, and
zirconium diboride.

22 FIG. 2 describes a fabrication method for various composites 4. Generally,

1 composites 4 are prepared from high-purity feedstock, mixed, formed into a solid, and
suffused with oil. One or more plates are adhered to the composite 4.

Feedstocks include both powders and liquids. Conductive filler 2 feedstock is typically composed of a fine, uniform powder, one example being 325 mesh titanium
5 carbide. Nonconductive matrix 3 feedstock may include either a fine, uniform powder or a liquid with sufficiently low-viscosity to achieve adequate dispersion of powder. Powder-based formulations are mechanically mixed and compression molded using conventional methods. Polytetrafluorethylene formulations may require sintering within an oven to achieve a structurally durable solid. Powder-liquid formulations, one example being
10 titanium carbide and a silicone-based elastomer, are vulcanized and hardened within a die under low uniaxial loading at room temperature.

The solid composite 4 is placed within a liquid bath thereby allowing infiltration of the additive into the solid. Additives are typically inorganic oils, preferably silicone-based. The composite 4 is exposed to the additive bath to insure complete
15 suffusion of the solid, whereby exposure time is determined by dimensions and composition of the composite 4. For example, a 0.125-inch by 0.200-inch by 0.940-inch composite 4 composed of titanium carbide having a volume fraction of 66 percent and RTV R3145 having a volume fraction of 34 percent was suffused over a 48 hour period.

Conductive or nonconductive plates are adhered to the composite 4 either
20 before or after suffusion. If prior to suffusion, plates are placed within the die along with the liquid state composite 4. For example, a silicone elastomer composite 4 is adequately bonded to two 0.020-inch thick brass plates by curing at room temperature typically
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1 between 3 to 24 hours or at an elevated temperature between 60 to 120 degrees Celcius
for 2 to 10 hours. If after suffusion, silicone adhesive is applied between plate and
composite 4 and thereafter mechanically pressed to allow for proper bond formation.

5 A porous, nonconductive matrix 3 improves compression and cooling
characteristics of the composite 4 without degrading electrical properties. A porous
structure is formed by mechanical methods, one example including drilling, after
fabrication of the solid composite 4. Another method includes the introduction of pores
during mixing of a powder-based conductive filler 2 with a liquid-based nonconductive
matrix 3. An additional method includes the introduction of pores during compression
10 forming the composite 4. Also, pores are formed by heating the composite 4 within an
oven resulting in localized heating or phase transitions that result in void formation and
growth. Furthermore, highly compressible microspheres composed of a low-density, high-
temperature foam may be introduced during mixing. Pores are either randomly oriented or
arranged in a repeating pattern. Pore shapes include but are not limited to spheres,
15 cylinders, and various irregular shapes. A single pore may completely traverse the
thickness of a composite 4.

FIGS. 13 and 14 show an embodiment wherein a plurality of holes 40 traverse
the cross section of a pressure switch 11. FIG. 15 shows an embodiment wherein holes
traverse the composite 4 within the pressure switch 11.

20 FIG. 16 shows a further embodiment wherein holes 40 are filled with a
temperature sensitive material 41, examples including rods or springs composed of a shape
memory alloy. Functionally, the temperature sensitive material 41 is typically a rubbery
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1 material below, see FIG. 16a, and hard above, see FIG. 16b, a phase transition
temperature. More importantly, the temperature sensitive material 41 produces a large
force above a transition temperature designed within the material as readily understood
within the art. This force is sufficiently capable of moving the pressure plates 18 or
5 electrodes 6,7 apart and interrupting current flow. The temperature sensitive material 41 is
self restoring thereby facilitating current flow after the surrounding composite 4 has
cooled.

FIGS. 17 and 18 show two embodiments wherein at least two temperature
sensitive actuators 51 apply a compressive force 22 onto a composite 4 thereby allowing
10 current flow. In FIG. 17, current flows directly through the temperature sensitive
actuators 51a, 51b, preferably a shaped memory alloy. When a fault occurs the
temperature sensitive actuators 51a, 51b are heated and contract thereby decompressing
the composite 4 and interrupting current. The composite 4 is compressed as the
temperature sensitive actuator 51 cools. In FIG. 18, current flows through the first
15 electrode 6 and the second electrode 7 when temperature sensitive actuators 51a, 51b are
heated by thermal elements 56a, 56b. Thermal elements 56a, 56b are deactivated when a
fault condition occurs thereby decreasing the length of the temperature sensitive actuators
51a, 51b and reactivated after the fault condition is corrected thereby increasing the length
of the temperature sensitive actuators 51a, 51b causing compression of the composite 4
20 and current flow.

FIGS. 5 and 6 show additional embodiments of the present invention
22 comprised of four pressure switches 11a, 11b, 11c, 11d, a first electrode 6, a second

1 electrode 7, two planar conductors 31a, 31b, four insulators 32a, 32b, 33a, 33b, a
restoration element 30, and a pair of actuators 19a, 19b.

Pressure switches 11a, 11b, 11c, 11d are composed of a pressure conduction
composite 4 disposed between and adhered to two electrically conducting plates, as
5 described above. A pair of pressure switches 11 are electrically aligned in a serial
arrangement about a single electrode, either the first electrode 6 or the second electrode 7.
One electrically conducting plate from each pressure switch 11 directly contacts the
electrode. Two such pressure switch 11 and electrode arrangements are thereafter aligned
parallel and disposed between, perpendicular to and contacting a pair of conductors 31a,
10 31b so that each pressure switch 11 in a serial arrangement contacts a separate conductor
31. Conductors 31 are composed of materials known within the art and should have
sufficient strength to resist deformation when a mechanical load is applied. Thereafter, an
insulator 32 is placed in contact with and attached or fixed to each conductor 31. A typical
insulator 32 is a planar element composed of an electrically nonconducting material with
15 sufficient strength to resist deformation when a mechanical load is applied.

At least one restoration element 30 is disposed between and parallel to the
serial arrangement of pressure switches 11 and electrodes 6 or 7. The restoration element
30 is attached to separate electrically nonconductive insulators 33a, 33b. Thereafter,
insulators 33a, 33b are mechanically attached to, perpendicularly disposed and between
20 the conductors 31a, 31b. Insulators 33a, 33b electrically isolate the restoration element 30
from conductors 31a, 31b. The restoration element 30 decompresses the composite 4
22 within each pressure switch 11, returning it to its original thickness, when the compressive

1 mechanical load is removed from the insulators 32a, 32b. A restoration element 30 may be
a mechanical spring or coil, a pneumatic device, or any similar device that provides both
extension and contraction.

5 In preferred embodiments, an actuator 19 contacts an insulator 32. In one
embodiment, at least one actuator 19 is attached or fixed to each insulator 32 opposite of
said conductor 31, as shown in FIG. 5. A pair of actively opposed yet equal actuators
19a, 19b apply a mechanical load by pushing onto electrically nonconductive insulators
32a, 32b to compress the composite 4 within each pressure switch 11a, 11b, 11c, 11d, as
shown in FIG. 5b. In another embodiment, at least two actuators 19a, 19b are
10 mechanically attached or fixed to a pair of insulators 32a, 32b, see FIG. 6. Again, a pair of
actively opposed yet equal actuators 19a, 19b apply a mechanical load by pulling on
electrically nonconductive insulators 32a, 32b to compress the composite 4 within each
pressure switch 11a, 11b, 11c, 11d, as shown in FIG. 6b.

Variations to the described embodiments also include at least two or more
15 actively opposed actuators 19 mechanically compressing one or more current controllers
1. FIG. 7 describes a three-by-three arrangement of nine current controllers 1, however
not limited to this arrangement. In such embodiments, current controllers 1 are electrically
connected parallel thereby providing a total power handling capability equal to the sum of
the power handling of individual units.

20 One or more actuators 19 may be employed to drive two or more current
controllers 1. For example, a single actuator 19 or two actively opposed yet equal
22 actuators 19 may apply a mechanically compressive load onto the current controllers 1 so

1 that all are simultaneously compressed and decompressed. Alternatively, one or a pair of
actuators 19 may apply a mechanically compressive load onto each individual current
controller 1. In this embodiment, it is possible to simultaneously drive all current
controllers 1 or to selectively drive a number of units.

5 The embodiments described above may also include a current measuring
device electrically coupled before or after the current controller 1. This device provides
real-time sampling of current conditions which are thereafter communicated to the
actuators 19. Such monitoring devices are known within the art.

An actuator 19 is a rigid beam-like element composed of an active material
10 capable of dimensional variations when electrically activated. For example, the actuator 19
may extend, contract, or extend and contract, as schematically represented by arrows in
FIGS. 5 and 6. Extension of the actuator 19 increases the overall length of the actuator
19. Actuators 19 are composed of electrically activated devices including piezoelectric,
piezoceramic, electrostrictive, magnetostrictive, and shape memory alloy materials. For
15 example, piezoelectric and piezoceramic materials may be arranged in a planar stack along
the actuator 19. Shape memory alloys are mechanically distorted by heating via electrical
conduction or heat conduction from an adjacent body, one example including the
composite 4 during fault condition. Alternatively, an actuator 19 may be a commercially
available high-speed piezo-controlled pneumatic element comprised of a pneumatic
20 diaphragm with pilot operated high-bypass valve.

An alternate embodiment of the current controller 1 is comprised of a first
22 electrode 6, a second electrode 7, an isolator 5, at least one pressure plate 18, and a

1 composite 4, as shown in FIG. 8. First electrode 6 and second electrode 7 are electrically
conductive and separately arranged parallel about a nonconducting isolator 5 and a
variably resistive composite 4. A compression mechanism 16 adjusts the force 22 acting
on one or more pressure plates 18 thereby contracting and expanding the composite 4.
5 Neither arrangement between first electrode 6 and second electrode 7 nor their function
are polarity sensitive and thereby bidirectional.

FIG. 8 describes a compression mechanism 16 comprised of two actively-
opposed actuators 19a, 19b constrained by a band 25 and attached to two movable
pressure plates 18a, 18b so to compress a composite 4. In this embodiment, each actuator
10 19 is fixed to the band 25 at a first end 20 and to a pressure plate 18 at a second end 21,
as shown in FIG. 10. Preferred pressure plates 18a, 18b are planar elements comprised of
a nonconductive material, preferably a ceramic, contacting the composite 4 in a symmetric
arrangement. First electrode 6 and second electrode 7, preferable planar shaped, contact
composite 4 along two separate surfaces perpendicular to those contacted by pressure
15 plates 18a, 18b. A two-part isolator 5a, 5b further contacts the composite 4 along two
additional surfaces. In the described arrangement, first electrode 6, second electrode 7,
pressure plates 18a, 18b, and isolator 5a, 5b surround and confine the composite 4, as
shown in FIG. 11. The composite 4 is volumetrically compressed when movable pressure
plates 18a, 18b displace the composite 4 by decreasing the confinement volume provided
20 by the arrangement of immovable electrodes 6, 7, immovable isolator 5a, 5b, and pressure
plates 18a, 18b.

22 In preferred embodiments, a pair of dynamic actuators 19a, 19b exert an equal

1 yet opposed force 22 onto a pair of pressure plates 18a, 18b thereby compressing and
pressurizing the composite 4. However, in an alternate embodiment, one active actuator
19a is sufficient to compress the composite 4 where opposed by a static or inactive
actuator 19b or functionally similar element.

5 Actuator 19 functionality requires the actuator 19 fixed at one end to prevent
movement so that linear extension and contraction within the actuator 19 is realized as
movement of the pressure plate 18. In one preferred embodiment, a band 25 directs
expansion of actuators 19 towards the composite 4 and prevents pressure relief by
restricting outward movement of isolators 5a, 5b.

10 FIG. 10 describes a nearly rectangular band 25, however other geometric
shapes are possible. A band 25 consists of a single-piece unit with attachment points for
actuators 19a, 19b and isolators 5a, 5b. For example, an actuator 19 may be rigidly
attached via threads, adhesive, or interference fit within a cavity 12, as shown in FIG. 10.
Furthermore, the band 25 may be slidably disposed and secured via sliders 8 dimensionally
15 similar to the channel 9 at both ends of the isolator 5, as shown in FIG. 12. Preferred
embodiments of the band 25 are composed of either a metal or a high-strength fiber-based
composite. The band 25 provides sufficient structural rigidity to maintain integrity of the
current controller 1 during mechanical compression of the composite 4.

20 FIGS. 9 and 10 show a dually opposed arrangement of a two-part isolator 5a,
5b about a composite 4. A typical isolator 5 may be either a single or two-part rectangular
solid, having a channel 9 at two opposed terminal ends 10a, 10b for securing a slider 8. In
22 the single-piece arrangement, a region is provided along the isolator 5 for the composite 4.

1 The slider 8 is dimensionally smaller than other regions of the band 25 thereby forming a
guide 23, as shown in FIG. 12. A pair of guides 23a, 23b along both sides of the isolator 5
restrict movement of the band 25 along the channel 9. The isolator 5 is composed of a
nonconducting material, preferably a ceramic. Planar-shaped first electrode 6 and second
5 electrode 7 are secured via fasteners or similar means to the isolator 5 further preventing
movement of isolator 5, first electrode 6, and second electrode 7 and maintaining pressure
within the composite 4. Actuators 19a, 19b may or may not prestress the composite 4
when assembled with band 25, isolator 5, first electrode 6, and second electrode 7.

The actuator 19 is a rigid beam-like element composed of an active material
10 capable of dimensional variations when electrically activated. For example, the actuator 19
may extend, contract, or extend and contract, as schematically represented by arrows in
FIG. 11. Extension of the actuator 19 increases the overall length of the actuator 19.
Contact between band 25 and actuator 19 at the first end 20 insures any dimensional
lengthening of the actuator 19 is manifested as movement of the pressure plate 18 into the
15 composite 4. Compression and pressure within the composite 4 increase with actuator 19
length. In one preferred embodiment, mechanical loading onto the band 25 during
extension of the actuator 19 is transferred to isolator 5 as a compressive load by the band
25. Contraction of the actuator 19 decreases actuator 19 length. Contact between band 25
and actuator 19 at the first end 20 insures any dimensional shortening of the actuator 19 is
20 manifested as movement of the pressure plate 18 away from the composite 4.
Compression and pressure within the composite 4 decrease as actuator 19 length shortens.

22 Actuators 19 are typically constructed from an active material, examples

1 including but not limited to piezoelectric, piezoceramic, electrostrictive, magnetostrictive,
and shape alloy materials. For example, piezoelectric and piezoceramic materials may be
arranged in a planar stack along the actuator 19. Alternatively, actuators 19 may include
commercially available high-speed piezo-controlled pneumatic element as described above.

5 Actuator 19 length is controlled by varying electrical current to a
piezoelectric, piezoceramic, and electrostrictive element or magnetic field within a
magnetostrictive element based on current flow conditions across the current controller 1
as measured by equipment known within the art. For example, current may be applied to
lengthen two actively opposed piezoelectric-based actuators 19a, 19b thereby compressing
10 a pressure conduction composite 4 and allowing current flow through the current
controller 1. Upon reaching a fault condition, current to the actuators 19a, 19b is
terminated shortening the actuators 19a, 19b and interrupting current flow through the
current controller 1. In an other example, a pressure conduction composite 4 is
prestressed by two actively-opposed piezoceramic-based actuators 19a, 19b. Upon
15 measuring a fault, current is applied to the actuators 19a, 19b shortening the actuators
19a, 19b and interrupting current flow across the current controller 1. The control circuit
regulating current flow to actuators 19a, 19b is readily understood by one in the art.

The description above indicates that a great degree of flexibility is offered in
terms of the present invention. Although embodiments have been described in considerable
20 detail with reference to certain preferred versions thereof, other versions are possible.
Therefore, the spirit and scope of the appended claims should not be limited to the
22 description of the preferred versions contained herein.